Patent Claims

1. A method of automated, computer-assisted plant occupancy planning in the process industry by means of an integrative relaxation approach for the sequencing of a discontinuous batch production and

allocation of resources over time to a set of operations arising from batch planning,

where during their execution the operations use resources, which may be available in multiples, and where productional restrictions are to be taken into account in carrying out the operations,

where the problem of plant occupancy planning to be optimized is modeled as a resource-constrained project scheduling problem, taking into account the productional restrictions, where each operation corresponds to an activity of the project, for which it is possible to define an execution mode, a start time and an completion time, where restrictions on the availability of required resources and temporal constraints are to be taken into account,

in a first step of the modeled problem, a relaxation which simplifies the resource problem is formed, disregarding the restrictions on the availability of resources, and taking into account the productional restrictions of the type of minimum and maximum time lags between operations and all the productional restrictions of the production break type which are independent of the selection of resources for operations,

in a second step for the relaxed problem of plant occupancy planning, the

temporal scheduling problem is solved as a calendarization problem in networks with the help of an iterative method,

where in a third step, the solution to the temporal scheduling problem is investigated for its feasibility with respect to the non-relaxed problem of plant occupancy planning,

where, when it is found that restrictions on the availability of resources are violated in the solution of the temporal scheduling problem, these violations are solved by introducing precedence relationships, and

if it is found that not all resources have been selected for carrying out an operation, those resources are selected,

the second step of temporal scheduling and the third step of introducing precedence relationships or selecting resources are continued until a feasible plant occupancy plan has been found or until the constraints to be taken into account in the second step of temporal scheduling are contradictory,

if a possibility investigated does not violate any productional restrictions, the plant occupancy plan is stored as a feasible solution,

investigation of possibilities according to the third step which have not yet been reviewed is continued,

and a best solution with regard to a selectable objective function that does not decrease in the completion times of the operations is determined from the feasible solutions determined in the second step.

2. A method in accordance with Claim 1, characterized in that several possibilities

of precedence relationships between competing operations are stored in the form of a decision tree.

3. A method in accordance with Claim 1, characterized in that several possibilities of resource selection are stored in the form of a decision tree.

4. A method in accordance with Claim 1, characterized in that the iterative method used in the second step is a label-correcting method.

5. A method in accordance with Claim 1, characterized in that in a plant occupancy plan which is investigated in the third step for whether it represents a feasible solution, the earliest start time or completion time of an operation at which one of the following conflicts occurs is determined:

a) the inventory in some storage facility exceeds the prescribed maximum inventory,

b) the inventory in some storage facility is lower than the prescribed minimum inventory,

c) the number of employees required exceeds the number of employees available,

d) the demand for processing units by operations and setups exceeds the number of processing units available,

e) an operation is started, but some resources required for its execution have not yet been selected.

6. A method in accordance with Claim 5, characterized in that conflicts a) through d) are checked in the priority sequence a) through d).

7. A method in accordance with Claim 5, characterized in that conflict e) is checked before conflicts a) through d) are checked.

8. A method in accordance with Claim 5, characterized in that conflict e) is checked after conflicts a) through d) are checked.

9. A method in accordance with Claim 5, characterized in that the existence of a conflict a) is checked by sorting the start and completion times of the operations in ascending order and then determining for each storage facility whether or not at the start time or completion time of an operation the sum of the maximum withdrawals and the minimum additions that have taken place by the respective point in time with respect to all possible selections of resources for all operations exceeds the maximum inventory.

10. A method in accordance with Claim 5, characterized in that the existence of a conflict b) is checked by sorting the start and completion times of the operations in ascending order and then determining for each storage facility whether or not at the start time or completion time of an operation, the sum of the minimum withdrawals and maximum additions that have taken place by the respective point in time with respect to all possible selections of resources for all operations is below the minimum inventory.

11. A method in accordance with Claim 5, characterized in that the existence of a conflict c) is checked by sorting the start and completion times of the operations in ascending order and then determining for each group of employees of the same qualification whether or not at the start time of an operation, the sum of the minimum demands on employees with respect to all possible selections of resources for all operations is greater than the available number due to the operations being carried out at that time.

12. A method in accordance with Claim 5, characterized in that the existence of a conflict d) is checked by sorting the start times of the operations in ascending order and then determining for each processing unit whether or not for all pairs of operations carried out on this processing unit,the time lag between the end of the first operation and the beginning of the second operation is sufficient for setup regardless of the selection of resources.

13. A method in accordance with Claim 5, characterized in that the existence of a conflict e) is checked by determining the set of selections of resources still possible for each operation, and if the set consists of a single element, it is assumed that the selection of resources has been made according to the element contained in the set.

14. A method in accordance with Claim 5, characterized in that in an investigated plant occupancy plan in which a conflict has occurred an attempt is made to solve the conflict.

15. A method in accordance with Claim 14, characterized in that a possibility is selected to resolve a conflict that has occurred, where precedence relationships are introduced or the feasible selections of resources are restricted, and the other possibilities are stored in a decision tree.

16. A method in accordance with Claim 14, characterized in that in a conflict case a), the possibilities of delaying the completion time of an operation which, by the time of the conflict has increased the inventories in the storage where the conflict occurred in all possible selections of resources, , are determined, at least delaying it until the earliest start time of an operation which after the conflict time reduces the inventories of the storage in which the conflict occurred in all possible selections of resources, and these possibilities are stored in the form of

precedence relationships.

17. A method in accordance with Claim 14, characterized in that in a conflict case b), the possibilities of delaying the start time of an operation which, by the time of the conflict has reduced the inventories in the storage where the conflict occurred in all possible selections of resources, are determined, at least delaying it until the earliest completion time of an operation which after the conflict time has increased the inventories of the storage in which the conflict occurred in all possible selection of resources, and these possibilities are stored in the form of precedence relationships.

18. A method in accordance with Claim 14, characterized in that in a conflict case c), the possibilities of delaying the start time of an operation which, by the time of the conflict has used the resource of employees of the same qualification where the conflict occurred in all possible selections of resources, are determined, at least delaying it until the earliest completion time of an operation which at the conflict time has used the resource of employees where the conflict occurred in all possible selections of resources, and these possibilities are stored in the form of precedence relationships.

19. A method in accordance with Claim 14, characterized in that in a conflict case d), the possibilities of delaying the start time of one of the two operations involved in the conflict at least until the completion time of the other operation involved in the conflict plus the setup time between the two operations are determined, and these possibilities are stored in the form of precedence relationships.

20. A method in accordance with Claim 14, characterized in that in a conflict case e), the possibilities of restricting the set of possible selections of resources for an operation starting at a conflict time to one element are determined, and these possibilities are stored in the form of the restricted sets.

21. A method in accordance with Claim 1, characterized in that the makespan is optimized, i.e., the period of time between the fixed start of production and the end of production, i.e., the completion of the last operation, is minimized.

22. A method in accordance with Claim 1, characterized in that the average lateness, i.e., the sum of the differences between the completion times and the given due dates for individual operations is minimized.

23. A method in accordance with Claim 1, characterized in that the maximum lateness, i.e., the maximum difference between the completion times and the given due dates for individual operations is minimized.

24. A method in accordance with Claim 1, characterized in that the sum of objective criteria weighted with any non-negative factors, such as makespan, average lateness and maximum lateness is minimized.

25. A method in accordance with Claim 1, characterized in that the productional restrictions of the total availability of the resources are taken into account.

26. A method in accordance with Claim 1, characterized in that the resources comprise groups of employees of equal qualification.

27. A method in accordance with Claim 1, characterized in that the resources comprise processing units.

28. A method in accordance with Claim 1, characterized in that the resources comprise inventories in storage facilities.

29. A method in accordance with Claim 1, characterized in that a quarantine time

after which they can be processed further at the earliest time is taken into account as a productional restriction for one or more output materials.

30. A method in accordance with Claim 1, characterized in that a shelf life time before which they must be processed further at the latest is taken into account as a productional restriction for one or more output materials.

31. A method in accordance with Claim 1, characterized in that a release date is taken into account as a productional restriction for one or more input materials.

32. A method in accordance with Claim 1, characterized in that a latest completion time for one or more operations is taken into account as a productional restriction.

33. A method in accordance with Claim 1, characterized in that production breaks are taken into account as a productional restriction for employees and processing units.

34. A method in accordance with Claim 1, characterized in that the availability of resources is taken into account as a productional restriction.

35. A method in accordance with Claim 1, characterized in that the limited usability of resources for certain operations is taken into account as a productional restriction.

36. A method in accordance with Claim 1, characterized in that a setup time for processing units is taken into account as a productional restriction.

37. A method in accordance with Claim 36, characterized in that the dependence of the setup time on the sequence of operations is taken into account as a

productional restriction.

38. A method in accordance with Claim 1, characterized in that the time-dependence of the availability of employees of equal qualification as resources is taken into account as a productional restriction.

39. A method in accordance with Claim 38, characterized in that production breaks are taken into account as a productional restriction.

40. A method in accordance with Claim 1, characterized in that the minimum and maximum inventories in storage are taken into account as a productional restriction.

41. A method in accordance with Claim 1, characterized in that the resources comprise one or more of the following resources: employees, processing units, inventories in storage facilities.

42. A method in accordance with Claim 1, characterized in that to one or more operations a set of alternative variants that differ in duration, the demand on resources as well as the materials consumed and the materials produced is assigned.

43. A computer-readable medium with a computer software product, which can be loaded directly into the internal memory of a digital computer and comprises the software code sections with which the steps of a method in accordance with Claim 1 are carried out when the product is running on a computer.

44. A method in accordance with Claim 1, characterized in that the plant is a multipurpose plant that produces final products from raw materials by means of chemical and/or physical transformation steps that are carried out in succession.